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The rare species *Synura lapponica* (Synurophyceae) new to the Czech Republic, local vs. global diversity in colonial synurophytes

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Abstract: *Synura lapponica* Skuja, a freshwater colonial flagellate (Synurophyceae, Stramenopila), has been reported for the first time in the Czech Republic. This study evaluates the ecological requirements of the species, and includes a survey of the literature. Although *S. lapponica* has been reported thus far only in the Northern Hemisphere, the probability of its bipolar distribution is relatively high (22%). Distribution is probably ecologically determined, water temperature (correlated with latitude or seasonal fluctuations), and lower pH seem to be the primary environmental variables. A local vs. global ratio reflects, to a certain extent, the degree of sampling effort expended in the studied area, but a considerable increase in the number of revealed taxa was apparent when the area was expanded.

Key words: *Synura lapponica*; Synurophyceae; distribution; ecological requirements; silica-scaled chrysophytes

Introduction

Synura lapponica is a freshwater colonial flagellate (Synurophyceae, Stramenopila), in which the scale-case often encloses the entire colony, not individual cells. *S. lapponica* was described by Skuja (1956), as sampled from a small pond in Abisko (Swedish Lappland), based on light microscopy observations. Later, Petersen & Hansen (1958) reexamined dried material on slides provided by Skuja and published electron microscopy images of silica scales. European reports of occurrence are based exclusively on scales examined by electron microscopy. Péterfi (1967) revealed scales in samples collected from a mountain peat-bog pool in Transylvania (Romania). Russian records came from samples of a water reservoir in the Volga cascade (Balonov & Kuzmin 1974). In Denmark, *S. lapponica* was confirmed from samples of two small ponds in Bornholm Island (Kristiansen 1975; Kristiansen 1978). It has also been found by researchers in Sweden (Skuja 1964, Cronberg & Kristiansen 1980) and Finland (Eloranta1985; Eloranta1989; Christie et al. 1988). North American records comprise both light microscopic observations of vegetative colonies accompanied by EM images (Wee 2001; Goldstein et al. 2005), and reports based solely on observations of separate scales. Munch (1985) revealed silica scales in the rich *S. lapponica* population of a core of recent sediments (ca. 100 years old) from a small kettle lake in Washington State (USA). Occurrence of the species in North Carolina (USA) was documented by Whitford & Schumacher (1984) and Wujek et al. (2004), and in South Carolina by Wujek et al. (2004). Siver (1987) found *S. lapponica* scales in two mesotrophic ponds in Connecticut (USA), and later, Siver & Lott (2000) discovered them in four lakes in New Hampshire (see survey of records in Table 1 or Fig. 1). Wee (2001) documented colonies covered with scales on a gelatinous envelope, as already observed and illustrated by Skuja (1956); moreover, Goldstein et al. (2005) described the morphology and reproduction strategies of colonies in this species. They observed unusual palmelloid forms of reproductive colonies as well as colonies exhibiting cellular dimorphism.

Fig. 1. A map of localities where *Synura lapponica* was recorded. The new Czech record is indicated by a cross.

Distribution patterns of synurophytes have been discussed in several papers. The question of whether these organisms are cosmopolitan, or whether some or most of them have limited biogeographical distributions, still remain to be answered. Biogeography is de-

Table 1. A survey of *Synura lapponica* records. To date, *S. lapponica* has been reported only in the Northern Hemisphere.

Country	Locality	pH	Conductivity (µS cm^{-1})	Temp. (℃)	Location		Reference
					Latitude	Longitude	
Europe							
Sweden	Many ponds and lakes at Abisko				68°21′ N	18°49′ E	Skuja 1964; Petersen & Hansen 1958
Finland	Kangaslampi lake in Salamajärvi National Park, western Finland	5.8	30		63°12′ N	24°38′ E	Eloranta 1985
	Isojärvi lake, Isojärvi National Park, western Finland lake sediments from eastern Finland Pitkäsjärvi lake, Finnish inland waters	7.2	38		61°41′ N	25°00′ E	Eloranta 1989 Christie et al. 1988 Hällfors & Hällfors 1988
Romania	mountain peat-bog pool in Transylvania				46°40′ N	23°31′ E	Péterfi 1966
Russia	Rybinsk Reservoir of the Volga cascade				58°30′ N	37°30′ E	Balonov & Kuzmin 1974
Sweden	oligotrophic clear water lake in central Småland			5.6–5.8	56°54′ N	14°33′ E	Cronberg & Kristiansen 1980
Denmark	heavily shaded small pond in Bornholm island small forest pond in Bornholm island	6.4 6.2	70 98	9.7 10.7	55° N	15° E	Kristiansen 1975; 1978 Kristiansen 1978
Czech Republic	mesotrophic pond in northern Bohemia	5.6	189	4.7	50°34′ N	14°42′ E	this study
North America							
USA – Connecticut	mesotrophic pond Bigelow mesotrophic pond Break Neck	6.1 6.1	37 28		41°59′ N	72°09′ W	Siver 1987
USA – New Hampshire	eutrophic lake French 3 oligotrophic lakes	8.1 6.1–7.0	54 22–44		42°52′ N	71°19′ W	Siver & Lott 2000
USA – Washington	small soft water kettle lake (recent sediments ca. 100 years old)				47°49′ N	122°18′ W	Munch 1985
USA – North Carolina	5 North Carolina Coastal Plain water bodies	3.8–6.0	36–80	13.5–17.0	34°05′ N – 35°20′ N	77°21′ W – 78°55′ W	Whitford & Schumacher 1984 Wujek et al. 2004
USA – South Carolina	18 South Carolina Coastal Plain water bodies	3.8–5.2	16–66	3.1–17.7	33°08′ N – 34°17′ N	79°58′ W – 81°40′ W	Wujek et al. 2004
USA – Maine	Lover Togus Pond				44°17′ N	69°41′ W	Wee 2001
Canada – British Columbia	oligotrophic Concil Lake Lubbe Reservoir Goldstream Reservoir				48° 30' N	123° 40' W	Goldstein et al. 2005

fined as the study of distribution of biodiversity over space and time (Martiny et al. 2006). Kristiansen (2001) and Kristiansen & Lind (2005) summarized the biogeographical data based on recent floristic records of *Mallomonas* and *Synura*. They established several distribution types. *S. lapponica* belonged to the northern temperate-subartic-arctic group of species, mainly occurring in the temperate regions of the Northern Hemisphere. However, Finlay et al. (2004) attempted to disprove the presumed occurrence of some protist species in one hemisphere only. According to the neutral dispersal model, protist species are expected to be found wherever the requisite environmental conditions exist. This is the so-called Baas-Becking hypothesis: everything is everywhere – the environment selects (Baas-Becking 1934). Ubiquitous dispersal in the silica-scaled genus *Paraphysomonas* (Chrysophyceae) was demonstrated by Finlay & Clarke (1999). Řezáčová & Neustupa (2007) evaluated ecologically (supporting the neutral model) versus geographically restricted distribution of selected *Mallomonas* species. They tested the probability of distribution of northern temperate species in both hemispheres. A low probability of bipolar distribution was found only in *Mallomonas multiunca*, *M. oviformis* and *M. punctifera* var. *punctifera*, indicating a geographically restricted highly nonrandom distribution of these species in the Northern Hemisphere only.

The purpose of the present study was to publish a new record of this rare species from the Czech Republic, and to evaluate its autecology (ecological requirements) and distribution pattern.

Material and methods

Four plankton net collections were made during the winter and spring months of 2007 from Břehyňský Pond (Northern Bohemia, Czech Republic). Water temperature, pH and conductivity were measured at the time of collection with Combo pH & EC (Hanna Instruments). Water samples were centrifuged or concentrated by sedimentation. Drops of the sample were dried onto formvar coated grids. Dried material was washed by repeated transfer of the grid into drops of ionized water dispensed on the hydrophobic surface of a Parafilm strip (Pechiney Packing). Dried grids were examined with a JEOL 1011 transmission electron microscope.

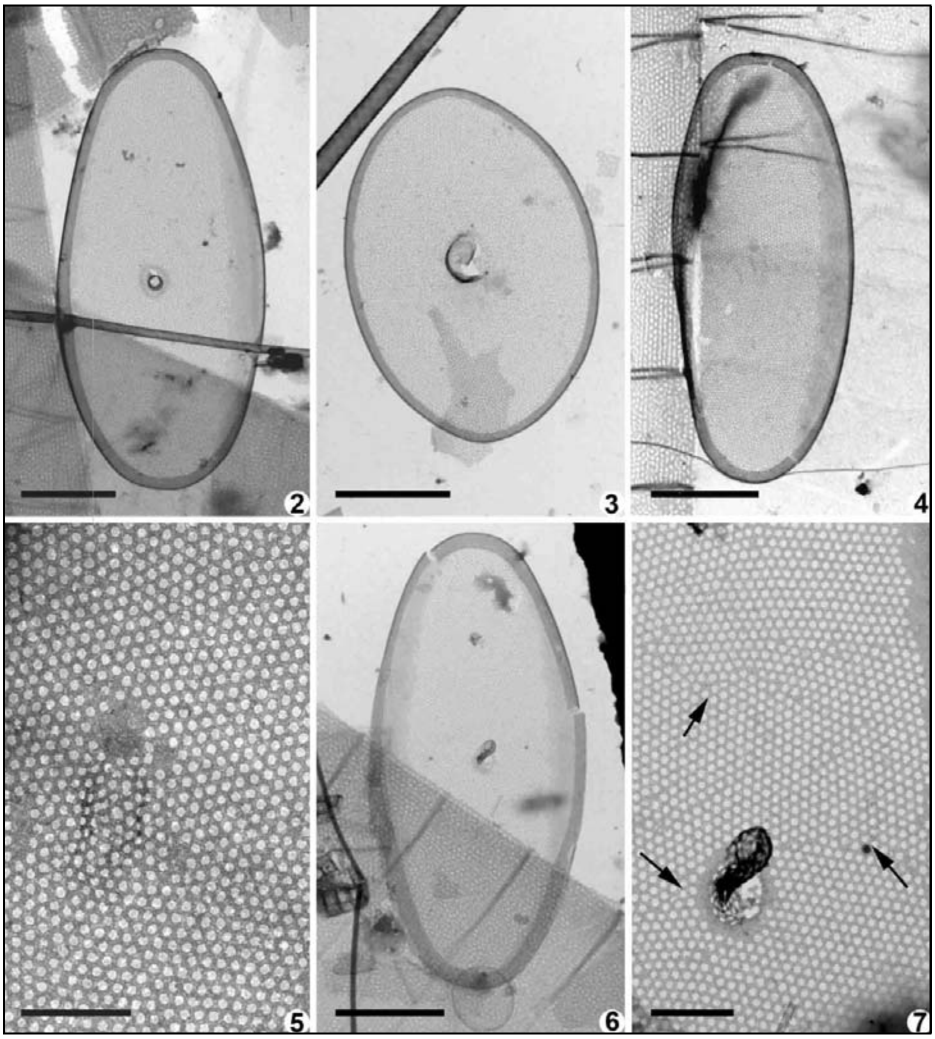
Results and discussion

Břehyňský Pond (50°34′45″ N; 14°42′13″ E) is a unique water-body preserved under The Ramsar Convention on Wetlands and Natura 2000. The pond was established in the 14th century on the remnants of a glacial lake, and has an elevated water level that prevented the terrestrialization of a peat bog. The area of the pond is 90 ha, and the depth does not exceed two meters (Mackovčin et al. 2002). The *Synura lapponica* population was collected in the March sample at a temperature of 4.7 ℃, pH 5.6 and a conductivity of 189 (μS cm^{-1}).

Siver & Hamer (1992) investigated the seasonality of silica-scaled chrysophytes and found *S. lapponica* to be a true winter species with its greatest abundance in December (when the water temperature did not exceed 5 ℃), therefore *S. lapponica* was ascribed to the cold-water group (Siver 1995). While in northern localities with low average water temperature, *S. lapponica* can occur year round, in water-bodies with higher summer temperatures, this species exhibits pronounced seasonal patterns. Based on a survey from the literature *S. lapponica* has been found between 3.1 ℃ and 17.7 ℃, i.e., at a weighted mean temperature of 9.5 ℃. Additionally, *S. lapponica* predominates in slightly acidic to neutral waters low in conductivity (Siver & Hamer 1992; Siver & Lott 2000). Its acidophilic nature is overwhelmingly supported by the literature. This taxon has been observed between pH 3.8 and 8.1, i.e., at a weighted mean pH of 5.1. Despite its reported preference for localities low in conductivity (weighted mean value of 44.7 μS cm^{-1}), *S. lapponica* was found in water of a relatively high conductivity during this study (189 μS cm^{-1}). This species was previously observed in oligotrophic (large to medium sized lakes, acid brown-water ponds) to eutrophic conditions, but exact nutrient concentrations have not been published; thus, trophic status estimation is dependent on the researchers' subjective evaluations.

Scales of *S. lapponica* are bilaterally symmetrical, 6.2–9.2 μm long, 3.3–4.4 μm wide with a more or less elliptical outline (length to width ratio 1.4–2.5). A hollow spherical protuberance is located in the center of the perforated base-plate. This structure is assumed to be rather fragile, because it often collapsed in TEM preparations (Figs 3, 6, 7). This protuberance is probably formed by a protrusion of periplastidial endoplasmatic reticulum into the silica deposition vesicle during scale biogenesis, and therefore, may be a structure homologous to the spine or keel in other *Synura* species. A hole on the ventral surface of the scale, corresponding to the protuberance on its dorsal surface, supports this view (see scanning electron microscopic images of scales in Goldstein et al. 2005). The hole is ca. 0.3 μm in diameter, while the diameter of the protuberance varies from 0.5 to 0.7 μm. Some of the scales lack the protuberance, but the central area is free of perforation (Figs 4, 5). Pores of the base plate are organized in regularly ordered longitudinal rows, although areas with a disrupted pattern may be detected (Fig. 7, arrows). In some scales, the perforation is excluded from the lateral margins (Figs 2, 4, 6). An upturned rim follows the entire circumference of the scale.

A similar protuberance on the dorsal surface of the base-plate was occasionally also observed on *Tessellaria volvocina* Playfair scales (Lavau et al. 1997; see their figs 14c, 14d), although a hole on the opposite surface has not been reported. That discovery supported the supposed affinity between *S. lapponica* and *T. volvocina.* The transfer of *S. lapponica* to the genus *Tessellaria* has been suggested on the basis of the structure of the scale-case, the scale similarity, and organization of the cells in the colony (Tyler et al. 1989; Lavau et al. 1997; Goldstein et al. 2005). Sequence data (18S,



Figs 2–7. *Synura lapponica* (Skuja) silica-scales: 2 – an oval scale with a developed spherical protuberance; 3 – a rounded scale with a collapsed protuberance; 4 – a scale lacking the protuberance; 5 – a detailed view of the Fig. 4, note the central area free of perforation; 6 – an oval scale; 7 – a detailed view of the Fig. 6, note the disturbed pattern in the rows of pores on the base plate (arrows). Scale bar: Figs 2–4, 6 bar 2 μm; Figs 5, 7 bar 0.5 μm.

ITS or cox gene) are needed to confirm the phylogenetic position of *S. lapponica*.

To date, *S. lapponica* has been reported only from the Northern Hemisphere, however, the probability of its bipolar distribution was calculated using the formula of Řezáčová & Neustupa (2007):

$$p = [Z/A] \times [(Z-1)]/(A-1)] \times \cdots$$
$$\cdots \times [(Z-(x-1))/A-(x-1))]$$

where Z is the number of independent floristic studies from the Northern Hemisphere, A is the number of all independent floristic studies worldwide and x is the number of *S. lapponica* reports. *S. lapponica* was only reported 19-times from the Northern Hemisphere. Overall, 101 worldwide reports ($A = 101$) were taken into account (94 from the Northern Hemisphere ($Z = 94$) and only 7 reports from the Southern Hemisphere). In the 94 reports from the Northern Hemisphere *S. lapponica* occurred in 19 ($x = 19$), while 76 did not include this species. A relatively high probability was ascertained (22%), indicating that distribution restricted to the Northern Hemisphere may be an outcome of chance. More intense examination of localities in southern temperate zones (southernmost South America) is essential to compile reliable data on *S. lapponica* distribution. Distribution is probably ecologically determined, and water temperature (correlated with latitude or seasonal fluctuations) and low pH seems to be the principal environmental variables.

Finally, we attempted to estimate the local *vs.* global diversity ratio in colonial synurophytes (genera *Synura, Tessellaria* and *Chrysodidymus* Prowse). The species concept is well established, although it is entirely based on the species-specific scale morphology. It is disputable whether certain forms (e.g. *S. petersenii* f. *kufferathii*; f. *petersenii* and f. *glabra*) should be discerned, because a continuous morphological gradient between the scale types is often reported (e.g. Nicholls & Gerrath 1985). Nevertheless, all of the species are relatively easy to determine. In the last more than 30 years only two new species have been described: *S. longisquama* (Wujek & Elsner 2000) and *S. obesa* (Němcová et al. 2008). Overall, 32 taxa have been described worldwide; if the forms and varieties are not consid-

Table 2. Local *vs.* global diversity ratio in colonial synurophytes.

		area (km^2)	No. of all taxa	local:global ratio (%)	No. of taxa when no varieties and forms discerned	local:global ratio (%)
global[1]			32	100	20	100
Local	Denmark[1]	43×10^3	11	34	9	45
	Czech Republic[2]	79×10^3	9	28	8	40
	Hungary[3]	93×10^3	8	25	6	30
Russia[4]		17×10^6	18	56	12	60

Number of taxa calculated according Kristiansen & Preisig (2007)[1]; Němcová et al. (2003 and unpubl. data)[2]; Barreto (2005)[3]; Voloshko & Gavrilova (2001)[4].

ered, that number is reduced to only 20 (Kristiansen & Preisig 2007). It is difficult to estimate global diversity, but it most likely will be in the tens of species, rather than the hundreds. A local versus global diversity ratio is expressed as a percentage of the global number of freshwater species. If organisms are cosmopolitan, the species recorded in local samples will represent a large fraction of the cumulative species pool identified in similar habitats around the world (Green & Bohannan 2006).

As a measure of the local diversity, we used the number of taxa revealed in three European countries (Denmark, Czech Republic and Hungary), where extensive research on silica-scaled chrysophytes has been conducted for a long period of time. In Denmark (Kristiansen & Preisig 2007) 11 taxa has been revealed (local *vs.* global ratio = 34%) and in the Czech Republic (Němcová et al. 2003) 9 taxa has been reported (local *vs.* global ratio = 28%), while in Hungary (Barreto 2005), in spite of a considerably larger area, only 8 taxa have been described (local *vs.* global ratio = 25%). The calculated values for the three European countries were compared to Russia (Voloshko & Gavrilova 2001) with 18 documented taxa (local *vs.* global ratio = 56%). Results are summarized in Table 2. A local *vs.* global diversity ratio for metazoan and vascular plant communities is usually less than 1% (Foissner 2006). Their present-day distribution is influenced by both evolutionary history and recent environmental conditions (Martiny et al. 2006). Partly, the local vs. global ratio reflects the degree of sampling effort expended in certain areas, but a considerable increase in the number of taxa revealed by extending an area is apparent. Existing literature on the biogeography of silica-scaled chrysophytes is based essentially on morphospecies (defined by the scale morphology). A more precise and less subjective definition of species must be established before we are able to provide a definite answer to the question of cosmopolitanism versus restricted distribution (Mitchell & Meisterfeld 2005; Green & Bohannan 2006). The existence of cryptic species and ecomorphs, defined as separate species, may considerably distort the data on biogeography. Initially, the question of congruence between morphologically and genetically defined species should be addressed.

Synura lapponica was considered to be a rare species primarily restricted to arctic and subarctic localities or mountain lakes (Péterfi 1966). Now it appears that this species has been often overlooked as water bodies in temperate zones were more often sampled in summer months than during the colder periods of the year. Wujek et al. (2004) reported *S. lapponica* from 23 Coastal Plain water bodies in the Carolinas (USA) during February and March, and Siver & Lott (2000) revealed the scales in the surface sediments of four lakes in New Hampshire (USA). Silica-scales remain in sediment after the organism has died, and thus reflect the species occurrence throughout the entire year.

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References

Baas-Becking L.G.M. 1934. Geobiologie of Inleiding Tot de Milieukunde. Van Stockkum & Zoon, The Hague.

Balonov I.M. & Kuzmin G.V. 1974. Species of the genus *Synura* Ehr. (Chrysophyta) in water reservoirs of the Volga Cascade. Akad. Nauk SSSR **59:** 1675–1686. (In Russian)

Barreto S. 2005. The silica-scaled chrysophyte flora of Hungary. Beih. Nova Hedw. **128:** 11–41.

Christie C.E., Smol J.P., Huttunen P. & Meriläinen J. 1988. Chrysophyte scales recorded in lake sediments from eastern Finland. Hydrobiologia **161:** 237–243.

Cronberg G. & Kristiansen J. 1980. Synuraceae and other Chrysophyceae from central Smaland, Sweden. Bot. Notiser **133:** 595–618.

Eloranta P. 1985. Notes on the scaled chrysophytes (Synuraceae, Chrysophyceae) in small lakes in and near Salamajärvi National Park, western Finland. Memoranda Soc. Fauna Flora Fennica **61:** 77–83.

Eloranta P. 1989. Scaled chrysophytes (Chrysophyceae and Synurophyceae) from national park lakes in southern and central Finland. Nord. J. Bot. **8:** 671–681.

Finlay B.J. & Clarke K.J. 1999. Apparent global ubiquity of species in the protist genus *Paraphysomonas*. Protist **150:** 419–430.

Finlay B.J., Esteban G.F. & Fenchel T. 2004. Protist diversity is different? Protist **155:** 15–22.

Foissner W. 2006. Biogeography and dispersal of micro-organisms: a review emphasizing prostists. Acta Protozool. **45:** 111–136.

Goldstein M., McLachlan J. & Moore J. 2005. Morphology and reproduction of *Synura lapponica* (Synurophyceae). Phycologia **44:** 566–571.

Green J. & Bohannan B.J.M. 2006. Spatial scaling of microbial biodiversity. Trends in Ecology & Evolution **21:** 501–507.

Hällfors G. & Hällfors S. 1988. Records of chrysophytes with siliceous scales (Mallomonadaceae and Paraphysomonadaceae) from Finnish inland waters. Hydrobiologia **161:** 1–29.

Kristiansen J. 1975. Studies on the Chrysophyceae of Bornholm. Bot. Tidsskr.**70:** 126–142.

Kristiansen J. 1978. Studies on the Chrysophyceae of Bornholm II. Bot. Tidsskr. **73:** 71–85.

Kristiansen J. 2001. Biogeography of silica-scaled chrysophytes. Beih. Nova Hedw. **122:** 23–39.

Kristiansen J. 2008. Dispersal and biogeography of silica-scaled chrysophytes. Biodivers. Conserv. **17:** 419–426.

Kristiansen J. & Lind J.F. 2005. Endemicity in silica-scaled chrysophytes. Beih. Nova Hedw. **128:** 65–83.

Kristiansen J. & Preisig H.R. 2007. Chrysophyte and Haptophyte Algae, 2nd part: Synurophyceae. In: Büdel B., Gärtner G., Krienitz L., Preisig H.R. & Schagerl M. (eds), Süsswasserflora von Mitteleuropa (Freshwater Flora of Central Europe), vol. 1/2, SpektrumAkademischer Verlag c/o Springer-Verlag, Berlin, 252 pp.

Lavau S., Saunders G.W. & Wetherbee R. 1997. A phylogenetic analysis of the Synurophyceae using molecular data and scale case morphology. J. Phycol. **33:** 135–151.

Mackovčin P, Sedláček M. & Kuncová J. 2002. Liberecko. In: Mackovčin P & Sedláček M. (eds), Chráněná území ČR, svazek III., Agentura ochrany přírody a krajiny ČR a Eko-Centrum Brno, Praha, 331 pp. (In Czech)

Martiny J.B., Bohannan B.J., Brown J.H., Colwell R.K., Fuhrman J.A., Green J.L., Horner-Devine M.C., Kane M., Krumins J.A. & Kuske C.R. 2006. Microbial biogeography: putting microorganisms on the map. Nature Reviews Microbiol. **4:** 102–112.

Mitchell E.A.D. & Meisterfeld R. 2005. Taxonomic confusion blurs the debate on cosmopolitanism versus local endemism of free-living protists. Protist **156:** 263–267.

Munch C.S. 1985. Chrysophycean scales as paleoindicators in the sediments of Hall Lake, Washington, U.S.A. Nord. J. Bot. **5:** 505–510.

Němcová Y., Neustupa J., Nováková S. & Kalina T. 2003. Silica-scaled chrysophytes of the Czech Republic. Acta Univ. Carolinae Biologica **47:** 285–346.

Němcová Y., Nováková S. & Řezáčová-Škaloudová M. 2008. *Synura obesa* sp. nov. (Synurophyceae) and silica-scaled chrysophytes from Abisko (Swedish Lapland). Nova Hedw. **86:** 243–254.

Nicholls K.H. & Gerrath J.F. 1985. The taxonomy of *Synura* (Chrysophyceae) in Ontario with special reference to taste and odour in water supplies. Can. J. Bot. **63:** 1482–93.

Péterfi L.S. 1966. Studies on the Rumanian Chrysophyceae (I). Nova Hedw. **13:** 117–137.

Petersen J.B. & Hansen J.B. 1958. On the scales of some *Synura* species II. Biol. Meddel. Dan. Vid. Selsk. **23:** 1–13.

Řezáčová M. & Neustupa J. 2007. Distribution of the genus *Mallomonas* (Synurophyceae) – ubiquitous dispersal in microorganisms evaluated. Protist **158:** 29–37.

Skuja H. 1956. Taxonomische un biologische Studien über das Phytoplankton schwedisscher Binnengewässer. Nova Acta Reg. Soc. Upsal., Ser. IV **16, 3:** 1–404.

Skuja H. 1964. Grundzüge der Algenflora und Algenvegetation der Fjeldgegenden um Abisko in Schwedisch-Lappland. Nova Acta Reg. Soc. Sci. Upsal., Ser. IV **18, 3:** 1–465.

Siver P.A. 1987. The distribution and variation of *Synura* species (Chrysophyceae) in Connecticut, USA. Nord. J. Bot. **7:** 107–116.

Siver P.A. 1995. The distribution of chrysophytes along environmental gradients: their use as biological indicators, pp. 232–268. In: Sandgren C.D., Smol J.P. & Kristiansen J. (eds), Chrysophyte algae, Cambridge University Press.

Siver P.A. & Hamer J.S. 1992. Seasonal periodicity of Chrysophyceae and Synurophyceae in a small New England lake: Implications for paleolimnological research. J. Phycol. **28:** 186–198.

Siver P.A. & Lott A.M. 2000. Preliminary investigations on the distribution of scaled chrysophytes in Vermont and New Hampshire (USA) lakes and their utility to infer lake water chemistry. Nord. J. Bot. **20:** 233–246.

Voloshko L.N. & Gavrilova O.V. 2001. A checklist of silica-scaled chrysophytes in Russia with an emphasis on the flora of Lake Ladoga. Nova Hedw. **122:** 147–167.

Tyler P.A., Pipes L.D., Croome R.L. & Leedale G.F. 1989. *Tessellaria volvocina* rediscovered. Br. phycol. J. **24:** 329–337.

Wee J.L. 2001. Light microscopic observations of *Synura lapponica* Skuja (Synurophyceae). Beih. Nova Hedw. **122:** 189–193.

Whitford L.A. & Schumacher G.J. 1984. A manual of fresh-water algae. Sparks Press, Ralcigh, North Carolina, USA, 337 pp.

Wujek D.E. & Elsner P.R. 2000. *Synura longisquama*, sp. nov., a new Synurophyte from South Carolina. J. Elisha Mitchell Sci. Soc. **116:** 97–100.

Wujek D.E., Cook J.L & Wright E.M. 2004. Identification, ecology, and distribution of silica-scale bearing chrysophytes from the Carolinas. III. Coastal Plain Region. J. North Carolina Acad. Sci. **120:** 1–25.

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